LETS LEVITATE

The Superconductor Hobby Club
1915 Zachary Drive, Salt Lake City, Utah 84116
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Volume 1 Issue 1
August 1987

Welcome to the world of Superconductivity. The Superconductor Hobby Club will keep you informed about the reinvigorated interest in Superconductors.

It is the editorial license that allows reintroduction of what most of you already may know, in this opening issue of this newsletter. Future issues will cover the latest developments in theory and applications.

HISTORY

It has been over seventy-five years since Dr. K. Onnes first showed the world that mercury can pass electricity without resistance. It is super that he identified the Oneness of electron flow without friction. But the progress has been subconductive due to the limitations of achieving very low temperatures, as that of liquid helium — below 4.2°K. This limited the fun only to the Physicists with access to very low temperatures, until recently.

The Superconducting properties of metals, alloys and intermetallic compounds were measured over the years. It is only normal, that one would expect zero resistance to electrical current flow at lower temperatures in materials such as metals that already have very low resistance. i.e. high conductivity, at normal temperatures.

But, the world of Physics and Chemistry are only human. In 1973, it was discovered that a mixture of lead, bismuth and barium oxide had a measurable superconducting transformation temperature of about 11.8°K.

But the progress was still slow, until Bednorz and Mueller, in 1986 identified superconducting transition temperature (Tc) at about 40°K, for a mixture of lanthanum, strontium and copper oxides; this is almost double that of the intermetallic niobium germanide at 23°K. Their feat was the extension of the work by scientists at Cannes in the early 1980's: the phenomenon of reducing resistance with temperature of the material (LaBaCuO4-x) cooked to be a catalytic reagent. Early 1987 saw the advent of still higher temperature of transition for SC's.

Chu and Wu announced Tc's around 90°K, in yttrium, barium and copper oxides. Now, this is a manageable coolness, with liquid nitrogen that boils at 77°K. Physicists, Chemists, Ceramicists, and hobbyists all over the world took off to cooking more variations of oxides of these and related elements of the periodic table. Scientific Journals across the world licensed all articles on this subject without the routine review by the Jurors. More than 500 articles have been published, with several thousands more waiting in line for the forthcoming months. News of room temperature Tc's flash across the globe, waiting to be verified.

LEVITATION

The superconductors not only pass electricity without resistance, but exclude magnetic fields when a magnet is brought near it. The magnets LEVITATE — float in the air above the SC's. Wouldn't it be useful if the roads are made of superconductors, and people with magnetic soles can just levitate rather than walk or climb, all of which gets to be tiring at times?

Meissner (1933), explained this levitation phenomenon occurring with superconductors. The Japanese already have a great development going in the field of levitation trains using SC's cooled with liquid helium. Other applications include capability of the SC's to switching very very very fast as is required by computers which are becoming faster and faster. People use this to measure very feeble magnetic fields such as brainwaves, to the generation of very very strong electromagnets, hundreds to thousands times stronger than used in motors, generators, etc.

This Newsletter is meant for the learned as well as the learners; articles by the readers are welcome. Let's levitate and join the sublime.
— Editor.

SCUIPS
(Superconducting quips)

This section covers some of the more recent happenings. Furuuchi Chemicals are marketing a $330 liquid nitrogen cooled superconductor kit. Join the line —

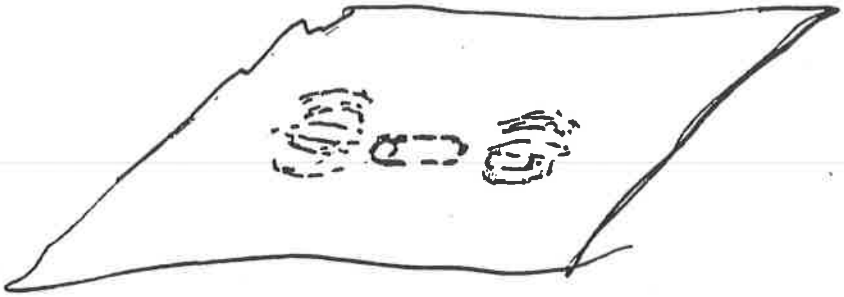
Fred Vahldiek, Dayton, Ohio is giving a speech at the Annual ACS Meeting (1987, New Orleans) on specially grown titanium boride singe crystals exhibiting superconductivity at 295°K (room temperature of 72°F). See oxides are not the only materials capable of higher Tc's —

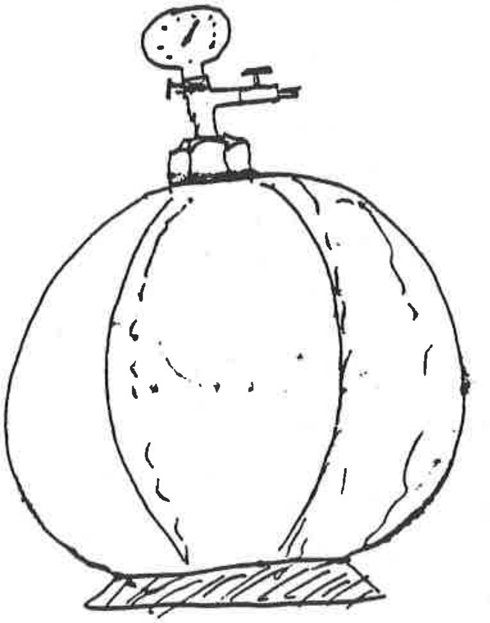
One should look up Nature magazine, to see what the rest of the world is cooking — It will be nice to know Chinese to be able to read their work too — Perhaps other languages?

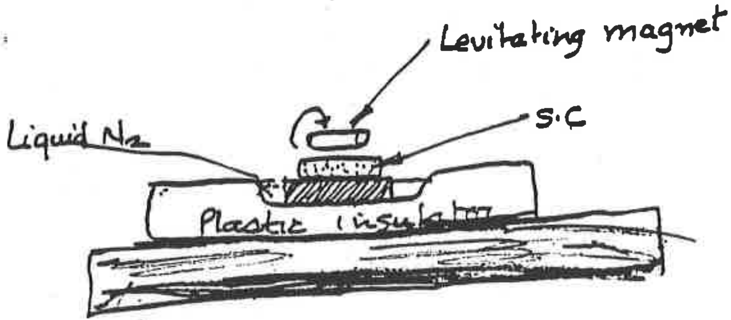
Still more theories to come on what makes them tick — We are still in the infancy in defining what compounds can be cooked to give what properties!!! Same as the first men who enjoyed cooked pig after it got in the fire by accident.

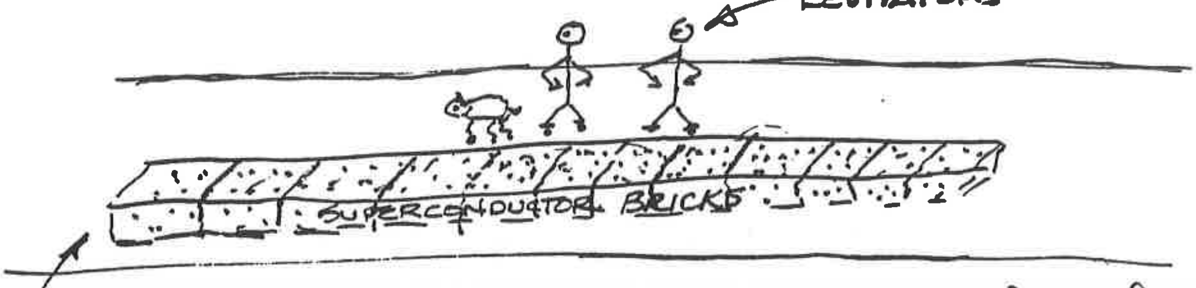
THOUGHTS ON 123 SC's

The yttrium, barium copper oxide SC's are called 123 SC's, for the chemical formula reads $Y_1Ba_2Cu_3O_{7-x}$. This is formed by combining one mole of Y_2O_3, four moles of BaO (as $BaCO_3$), and six moles of CuO, containing 13 oxygen atoms. When formulated it can at best give two moles of $Y_1Ba_2Cu_3O_{6.5}$, but doping with oxygen lets the number of oxygen atoms to go higher than 6.5 and closer to 7.0. It is necessary for









@airports
& even roads !!!

R Neelamegham
aug '87

that to happen to produce the superconducting composition. I still cannot understand why people continue to call inefficient oxygen enrichment as oxygen deficiency?

Basic inorganic chemistry gives a lot of clues, as to what happens to the inadequate oxygen enrichment. Take a mixture of these oxides, press into pellets or tablets, and cook for upto 3 days at 925°C. Cooking a Luau doesnt take that long. Let's look at the temperature 925°C — high enough to start decomposing CuO to Cu_2O and oxygen. This will make the initial brew (by the way green in color), to have oxygen less than 6.5 for each 123. Then cool the sample down to room temperature, grind it and repelletize into a tablet. Now anneal it (reheat) to between 500° and 800°C in oxygen, the green pill breathes all the oxygen it can take, becomes dark brown, and lets the 123 get O_{7-x}; this takes between 12 and 24 hours. Cool it down to room temperature, keep it away from moisture and carbon dioxide. Take a small plastic dish, keep this dollar size pill, pour liquid nitrogen over it to cool it close to 90°K, bring a tiny magnet over it and watch it levitate! The magnet keeps spinning eighth to quarter inch away from the SC.

It's fun, almost like the first time one observes how iron filings dance and arrange themselves along the field lines, when a magnet is kept below the paper holding the filings.

Anyone can get addicted to superconductors, even without the ability to measure the current flow without voltage drop, and magnetometers to guess the gausses of magnetism, etc —

- R. Neelameggham.

Next Issue

SQUIDS: Why not other compounds? Later developments & much more. Readers Forum (readers please contribute).

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Superconducting Quantum Interference Devices (SQUIDS)
Part I

Basic Principles

SQUID is a superconducting quantum interference device which operates on the basis of two essential and important physical phenomena: the flux quantization and Josephson Tunneling.

Flux quantization can be explained in a simple way as follows: current induced in a superconductor, which is carried by cooper pair electrons, generates a magnetic flux. The generated magnetic flux cannot take arbitrary values, but is quantized in units of flux quantum Øo which is the ratio of Planck's constant to the charge of a cooper pair, h/2e. Thus the enclosed flux is an integral multiple of the flux quantum Ø=nØo, n=0,1,2, ...

Josephson Tunneling named after Nobel Laureate Brian Josephson, is a superconductive tunneling process through a small discontinuity, where the discontinuity separates two sandwiched superconductors. The discontinuity, for example, can be in the form of either a constriction, point contact, or a thin insulating tunnel barrier, which is approximately 20 angstroms thick. The barrier is so thin, that it is possible for electrons to tunnel through it. Of the electrons which arrive at the barrier, something like one part in 10^{18} will tunnel through.

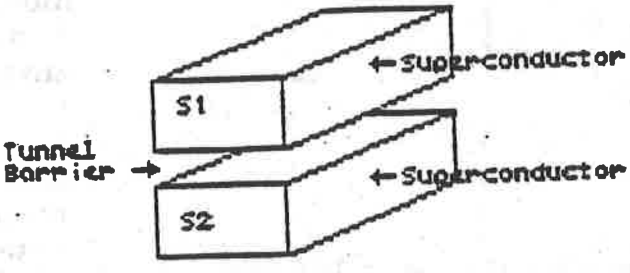

Figure 1.

Figure 1 shows the structure of two superconductors separated by a barrier which is also called the Josephson Junction (JJ).

Figure 2 shows a typical example of a characteristic obtained from a JJ. Plotted in Figure 2 is the current through the barrier as a function of voltage across the junction.

The characteristic has two parts. In one part, the voltage across the barrier is zero, and yet there is current flowing through it. This being a current without voltage, is a supercurrent just like the sort of current which flows in a bulk piece of superconducting wire.

In the second portion of the characteristic there is a finite voltage and the barrier is behaving as if it is resistive. This part of the characteristic is non-linear.

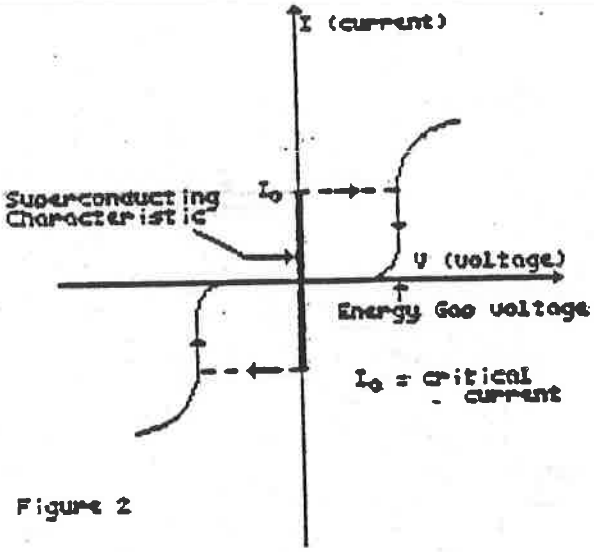

Figure 2

Josephson also showed that the difference (d) between the phases on the two sides of the junction is related to the supercurrent (i) flowing through the barrier by the relation sine d = i/i0: where i0 is the critical current, the maximum that the junction can sustain. For applied currents greater than the critical current, a voltage exists across the junction.

Superconducting Quantum Interference

Robert Jaklevic et al., were the first to demonstrate quantum interference between two JJs connected in parallel. As they changed the magnetic flux (Φ) associated with the superconducting loop, the critical current of the junctions oscillated with a period equal to the flux quantum Φ_0. These oscillations arise from interference between superconducting electrons going through the two barriers similar to interference between two coherent light beams in a diffraction grating experiment leading to dark and bright fringes. This phenomena of "Superconducting Quantum Interference" forms the basis of operation of SQUIDS.

-G. Radhakrishnan.

More next time ——

SCUIPS

(Superconducting Quips)

Additional work continues in the YBC world of superconductors, with more international participation. In August, Malaysia announced its entering the field.

Several announcements of higher and higher superconducting transition temperatures without detailed disclosures of the compounds have been made. Some talk about zero or near zero resistance between minus 35 to plus 65 degrees Celsius, without showing the Meissner Levitation effect of exclusion of magnetic field.

Among the compounds discussed across the globe, $Y_2(Ba,Sr)_2Cu_3O_8$ is predominant; the first announcement was seen in the June 4th issue of Nature. Mr. Vahldiek's presentation at the ACS Meeting on September 1, is an excellent scientific work describing zero resistance in specially made titanium boride single crystals at 22 deg C.

The hottest news now is the application of explosion cladding (encapsulation) technology in making 4 to 6 inch diameter rings of copperclad YBC. This is probably the largest bulk conductor made todate with the highest connectivity. The inventors are L.E.Murr, N.G.Eror (Beaverton,Oregon) and A.W. Hare (Sequim, Washington).

(Contd on page 6)

Superconductors from the Mineral Processing Point of View

The three steps involved in the making of a Superconducting ceramic material are:

1) Mixing the Powders of the constituents, usually oxides;

2) Obtaining a pellet of the resultant mixture by compaction in an appropriate die;

3) Sintering the pellet at appropriate temperature, and annealing it in oxygen to obtain the desired phase of ceramic.

The purpose of the step 1 is to ensure maximum connectivity between the constituents of the super conductor thus optimizing its performance. In this step, appropriate amounts of powders of the constituents are suspended in a suitable solvent, usually water, and the suspension is subjected to a gentle tumbling action using ceramic grinding media for 12 to 24 hours.

Use of water as a solvent, though inexpensive, has certain drawbacks. Many systems including oxides, silicates and semisoluble salts develop surface charge when suspended in water through the formation and subsequent dissociation of surface acid groups.

The charge development is a function of the pH of the suspension. In the case of quartz, the surface is positively charged when the suspension pH is below 1.8, and negatively charged at higher pH values. At pH 1.8, the surface is uncharged, and it is termed point-of-zero-charge, PZC. The PZC for any given oxide depends on the nature of the hydrolysis reaction for that oxide or its tendency to act as a weak acid. Table 1 lists PZC values for various oxide types.

Thus, if the suspension pH is not carefully chosen, the development of surface charge may lead to particles repelling each other and hence poor connectivity. It is desirable to maintain a suspension pH that would minimize the surface charges so that good dispersion of the powders is achieved.

In the case of binary mixtures, suspension pH may be maintained at a level which is in between the PZC values of the oxides involved. For example, to mix MgO (PZC = 12.4) and Cr_2O_3 (PZC =7.0) the suspension pH may be fixed at 9.5. At this point, the surface of the MgO powders would be positively charged while that of Cr_2O_3 would be negatively charged. The resultant attraction would result in good connectivity.

Another problem of using water as a solvent is that during the evaporation of the suspension to drive out water after mixing, it tends to leave a hardened agglomerate which may have to be reground and remixed. This is due to the relatively high boiling point of water and or high decomposition temperature of some of the oxides which gets hydrated (molecularly bound water).

Both these problems may be avoided if a non-polar solvent, such as cyclohexane, is used instead of water for dispersing the powders. Cyclohexane boils at about 62 deg C. Hence, by dispersing the powders in cyclohexane thoroughly and evaporating the suspension slowly, finely divided powders can be obtained. An added advantage of using this solvent is that any residual cyclohexane present in the mixture would act like a binder thus facilitating easy flow of the mixture during compaction. As a result addition of external binders is not required during step 2.

However, these non-polar solvents are fairly expensive. Hence, care must taken to recover these solvents to the maximum extent during evaporation and recycle them.

TABLE 1. Point Of Zero Charge Values For Various Oxide Types

OXIDE TYPE	EXAMPLES	PZC (pH)
M20	Cu20, Li20	> 11.5
MO	MgO,CuO,BaO	8.5 - 12.5
M203	Y203,A1203,Cr203	6.5 - 10.5
M02	Zr02,Si02	0.0 - 7.5
M205	Mo205	< 0.5
M03	Cr03	< 0.5

S. Gopalakrishnan.

WHY NOT OTHER COMPOUNDS? Part 1

The basic composition that first showed about 90 deg K transition temperature for superconductivity is YBC (yttrium- barium-copper oxides). Since that time, it has been shown that yttrium can fully be substituted by most of the lanthanide elements, such as shown in the table on 'Some High Tc Formulations" in the next page.

This table also shows the calcining (initial heating) and sintering (heating the pressed powder to form a connective pellet by allowing the powder particles - grains - to join together) conditions.

The table does not show the cooling rate following both the calcination and sintering steps. In most cases, it has been reported that the samples are cooled in the furnace, by turning the heater off. The cooling rate is usually about 2 deg C per minute.

It is also shown in the table that it is always not necessary to have an oxygen atmosphere in the furnace, even an air atmosphere is capable of allowing the superconducting phases to be developed - unless the air in Japan has more oxygen than elsewhere!!!! The use of oxygen atmosphere mainly helps in assuring the transformation, provided other heating and cooling conditions are kept in reasonable control.

Information regarding other compounds tested will be provided in the forthcoming issues of Let's Levitate. Several variations of the effects of partial substitutions of Barium and Copper have been published. In most cases, these partial substitutions lower the Tc.

R. Neelameggham

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SOME HIGH Tc FORMULATIONS

COMPOUNDS	Tc	CALCINE FOR			SINTER FOR		
& ADDITIVES	DEG K	DEG C	HOURS	ATM.	DEG C	HOURS	ATM.
Ba(1-x)Ln(x)CuO(3-y) [1]							
Ln=La;x=0.34	37	950	4	AIR	950	24	AIR
Ln=La;x=0.20	5	950	4	AIR	950	24	AIR
Ln=Ce;x=0.34	2	950	4	AIR	950	24	AIR
Ln=Ce;x=0.20	2	950	4	AIR	950	24	AIR
Ln=Pr;x=0.34	2	950	4	AIR	950	24	AIR
Ln=Nd;x=0.34	82	950	4	AIR	950	24	AIR
Ln=Nd;x=0.20	79	950	4	AIR	950	24	AIR
Ln=Nd;x=0.50	2	950	4	AIR	950	24	AIR
Ln=Sm;x=0.34	84	950	4	AIR	950	24	AIR
Ln=Sm;x=0.20	85	950	4	AIR	950	24	AIR
Ln=Sm;x=0.40	38	950	4	AIR	950	24	AIR
Ln=Sm;x=0.50	2	950	4	AIR	950	24	AIR
Ln=Eu;x=0.34	87	950	4	AIR	950	24	AIR
Ln=Eu;x=0.20	85	950	4	AIR	950	24	AIR
Ln=Eu;x=0.40	60	950	4	AIR	950	24	AIR
Ln=Eu;x=0.50	2	950	4	AIR	950	24	AIR
YBa2(Cu(1-x),Ag(x))3 OXIDES [2]							
x=0.0	93	900	5	AIR	900	10	AIR
x=0.1	86	900	5	AIR	900	10	AIR
x=0.2	91	900	5	AIR	900	10	AIR
x=0.4	89	900	5	AIR	900	10	AIR
x=0.6	31	900	5	AIR	900	10	AIR
Ho(0.37)Ba(0.5)Cu(1) OXIDES [3]							
	90	850	2	AIR	800	1	AIR
HoBa2Cu3O(7-d) [4]	93.4	950	4	OXYGEN	950	12	OXYGEN
ErBa2Cu3O(7-d)	93.2	950	4	OXYGEN	950	12	OXYGEN
A2Ba4Cu6O(14+y) [5]							
A=Y	92.3	950	2	OXYGEN	1100	5	OXYGEN
A=La	67.5	950	2	OXYGEN	1100	5	OXYGEN
A=Nd	86.4	950	2	OXYGEN	1100	5	OXYGEN
A=Sm	83.8	950	2	OXYGEN	1100	5	OXYGEN
A=Eu	92.2	950	2	OXYGEN	1100	5	OXYGEN
A=Gd	91.3	950	2	OXYGEN	1100	5	OXYGEN
A=Dy	91.6	950	2	OXYGEN	1100	5	OXYGEN
A=Ho	92.4	950	2	OXYGEN	1100	5	OXYGEN
A=Er	92.1	950	2	OXYGEN	1100	5	OXYGEN
A=Tm	89.7	950	2	OXYGEN	1100	5	OXYGEN
A=Yb	91.3	950	2	OXYGEN	1100	5	OXYGEN
A=Ce	-	950	2	OXYGEN	1100	5	OXYGEN
A=Pr	-	950	2	OXYGEN	1100	5	OXYGEN
A=Tb	-	950	2	OXYGEN	1100	5	OXYGEN
A=Lu	-	950	2	OXYGEN	1100	5	OXYGEN

From page 2)

Their article on this subject can be read in Nature, September 3rd issue. The reproducibility of properties in this composite is apparently better than attempts with encapsulating YBC in silver tubes drawn into wires, and similar concepts. In explosion cladding, YBC powder enriched in oxygen is encapsulated with several thousands of atmospheres of pressure generated by the explosion.

Another great stride towards making bulk YBC superconductors has been the work of AT&T researchers Jin, Tiefel, Sherwood, Kammiott & Zahurak. Their work on Fabrication of dense YBC superconductor wire (2 to 4 cm long and 1.5mm dia) by molten oxide processing is published in Applied Physics Letters (Sept 21, 1987).

Here the mixture of oxides/carbonates is melted to 1200-1300 deg C in a laboratory blow torch flame, and drawn into fibres, which was then given the various heat treatments in oxygen to enrich the phases with more oxygen than the initial starting stoichiometry to obtain the superconducting properties. Now we only have to wait for the next step where longer and flexible wires and other shapes are announced.

High School students in England, (New Scientist, July 9,1987) and USA (New Scientist, July 31, 1987) have demonstrated that YBC compounds exhibiting Meissner effect can be made by most small science laboratories, or those who have access to ceramic hobby kilns and oxygen.

The Superconductivity Hobby Club now has members from around the world. Several persons have commended the Club's efforts in promoting interest and awareness in this field.

One of the best review articles on YBC superconductors, is the one published by E. M. Engler in Chemtech Magazine (Sept 1987).

Edmund Scientific is apparently marketing low cost Superconducting Ceramic pellets for hobbyists.

Editor

Next Issue:
A few comments on conducting polymers - polyacetalyne, polypyrrole, polythiophene etc.

Polyaniline use in lithium batteries.

We welcome articles, comments & letters from our readers

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Volume 1 Issue 3

December 1987

The Defect Perovskite Structure

Ashok Khandkar

The relatively recent discoveries of ceramic materials which exhibit superconductivity have fueled interest in a well known class of materials, chiefly oxides which possess a structure known as *the defect perovskite structure*.

The perovskite structure belongs to a family of structures represented by the formula ABX_3 (where A and B are cations or positively charged atoms such as Ca, Fe, La or Y; and X is the anion typically oxygen). Many structural groups can be represented by the ABX_3 formula: calcites, perovskites and pyroxenes.

Such structures occur commonly in many minerals. Calcite ($CaCO_3$) is one of the commonest minerals and is found as Oolitic calcite sand on the shores of the Great Salt Lake, Utah. Of the ABO_3 phases, the perovskite compounds are perhaps the most widely studied.

The term *perovskite* stems from the name given to the mineral perovskite, $CaTiO_3$. The term is used in a general sense while referring to compounds with the formula ABX_3. However ABX_3 structures with cubic symmetry are known as *ideal perovskites*, other compounds which generally belong to orthorhombic, tetragonal or rhombohedral symmetries are *distorted* variants.

Ideal Perovskite Structure

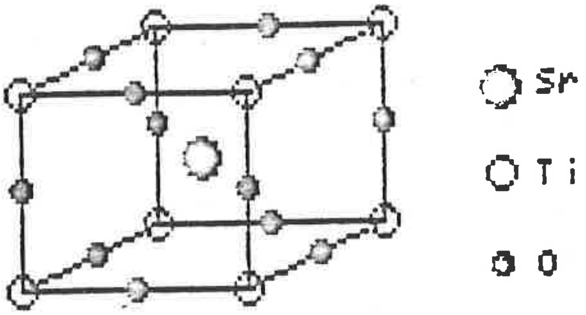

Fig 1: $SrTiO_3$
Schematic of Ideal Perouskite Structure

The ideal perovskite structure (IPS) typified by $SrTiO_3$, has an arrangement as shown in figure 1. The Ti atoms are located at the corners of the cube, the Sr at the body center of the cube and the O atoms lie at the center of the 12 edges of the cube.

Several compounds with this structure occur commonly in nature. Compounds deficient in cations or anions or both such as $SrFeO_{3-x}$ also exist. The compound ReO_3 can be considered as an IPS with the A ion missing. The distorted forms of IPS progress from cubic to tetragonal to rhombohedral to orthorhombic in decreasing order of symmetry.

Tetragonally Distorted Variant

This crystallographic variation resembles the cubic, except that one of the axes, the vertical or 'c' axis is longer or shorter than the other two. An example is the ferroelectric compound $BaTiO_3$. This material is characterized by a distorted TiO_6 octahedron as shown in figure 2.

Crystallographic studies have shown that Ti-O distances vary from one at 1.86 A^0, at 2.00 A^0 and one at 2.17 A^0.

Such a distortion causes polarization of the cation due to the asymmetry of the changes surrounding it.

The spontaneous polarization caused by the distortion of the metal-oxygen octahedron can be reversed by an applied electric field. This switching is called ferroelectricity by analogy with ferromagnetism.

Another tetragonal perovskite is $PbTiO_3$. In this material the PbO_5 octahedron is more distorted and consequently more polar. Hence the Curie temperature of $PbTiO_3$ is higher (490^0) as compared to $BaTiO_3$ (120^0).

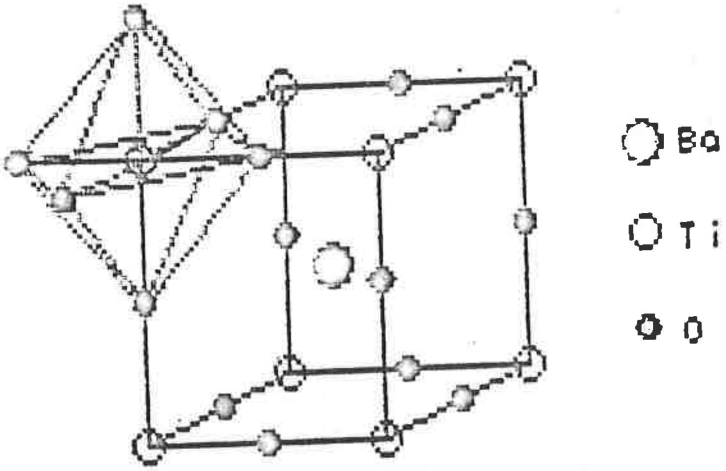

Fig 2: $BaTiO_3$ Schematic of tetragonal Perovskite Structure

Rhombohedrally Distorted Perovskites

This structure is typified by the compound $LaAlO_3$. The rhombohedral structure can be described as one having a hexagonal cell with two horizontal axes intersecting at 60^0 and a third vertical axis intersecting at 60^0. These materials are also of technological significance, exhibiting ferroelectric behavior.

The compound $LaCoO_3$ is of particular interest as high temperature electrode material: when suitably doped it behaves as a semiconductor with the electrical conductivity increasing with increasing temperature. At around 900^0C the material undergoes a phase transition from the rhombohedral to the cubic or pseudo cubic structure and exhibits metallic behavior. In such materials the electrical properties are related to the structure and the stoichiometry. At the higher temperatures the electrical properties will most likely be controlled by defects on the oxygen sub-lattice due mainly to the transition metal cation-oxygen pair forming the conduction band.

Orthorhombic Perovskites

This structure is typified by $GdFeO_3$ and is described by three intersecting axes a right angles to each other. As in the IPS, this structure also consists of a network of BO_6 octahedra in three dimensions with the octahedra distorted and tilted. A large number of compounds exist with this structure: $YFeO_3$, $LaYbO_3$, $CdTiO_3$, $NaTaO_3$, and $NaNbO_3$.

Similar to other perovskites, these materials also exhibit ferroelectric properties arising from the asymmetrical bonding of the metal-oxygen octahedra.

Ordered Perovskites

The discussion so far has centered mainly on compounds containing a single cation (or metal ion) on the octahedral A site; only broad classes of distorted perovskites have been considered. An important variant of this class of structures is the ordered perovskite as $A(B_1, B_2)_1O_3$ where B_1 and B_2 are two octahedral cations.

In some cases these cations occupy octahedral sites at random (not considered in this article). In other cases, ordering takes place with the two different cations occupying distinct crystallographic sites. Examples of such compounds are La_2NiIrO_6 and $Ba_3SrTa_2O_9$.

Note that the two compounds can be written as: $2[La(Ni_{0.5}Ir_{0.5})O_3]$ & $3[Ba(Sr_{0.33}Ta_{0.67})O_3]$.

Superconducting Yttrium Barium Cuprate

The structure of the oxide can be described as an ordered orthorhombic perovskite. On the basis of the formula $YBa_2Cu_3O_9$, the structure can be schematically shown as in figure 3. It can be vitualized as an ordered stacking of two $BaCuO_3$ separated by a plane of Y and O atoms.

The actual composition of the superconducting phase is described by $YBa_2Cu_3O_{9-x}$ where there are ordered vacancies of oxygen in the structure. The ordered oxygen vacancy may leave no oxygen atoms in the Y plane and two vacancies on the CuO_2 plane (top and bottom planes of the unit cell). This ordered vacancy array reduces the number of oxygen ions per unit cell to 7 and thus the superconducting phase is also referred to as $YBa_2Cu_3O_{7-x}$.

The structure of this compound is thought to be closely related to the superconducting property. The structure-property relationships are currently under intense investigation at several laboratories around the world.

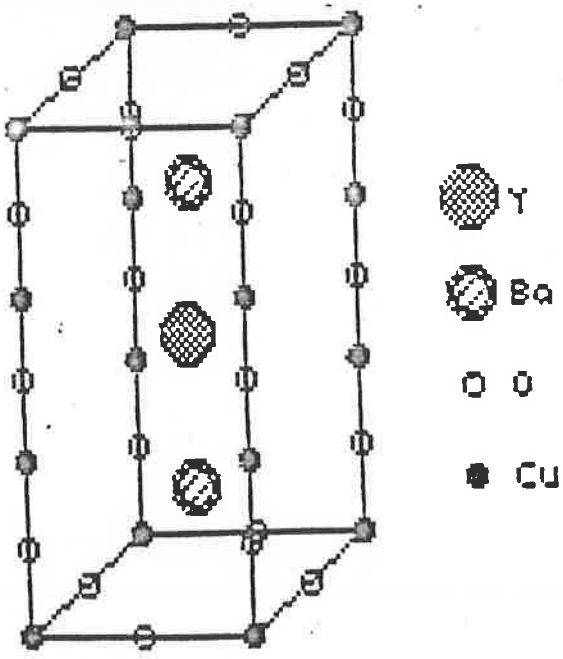

Fig 3: $Y_1Ba_2Cu_3O_9$
Orthorhombic
Structure

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2. *"Structure-Property Relations"*, R.E Newnham, Springer-Verlag, 1975.

3. *"The Development of High T_c Superconductors: An Introduction"*, D.R Clarke, Adv.Cer.Mat., Vol.2, No. 3B, July 1987.

Conducting Polymers: An Introduction

Ramesh Subramaniam

Conducting polymers are rapidly gaining importance, with promising applications in many areas including semiconductor devices, solar cells and batteries. During the 70's and even in the early 80's, it was thought that polymers cannot be both soluble and conducting at the same time. However, recently a certain class of polymers — Polythiophene — was found to have both properties.

Furthermore, polymers could be doped to increase their conductivities in a manner similar to inorganic semiconductors like silicon. But, superconducting polymers are yet to come.

Figure 1 compares the approximate conductivities of the various organic and inorganic materials [1]. The conductivities of materials that can be doped are listed in the undoped and heavily doped states (underlined).

At present, iodine doped polyacetylene with conductivities as high as 20,000 ohm^{-1} cm^{-1} have been obtained [2]. It has also been reported that certain oriented polyacetylenes exhibit conductivities in the range of $1.5*10^5$ ohm^{-1} cm^{-1} — quite close to that of copper [3]

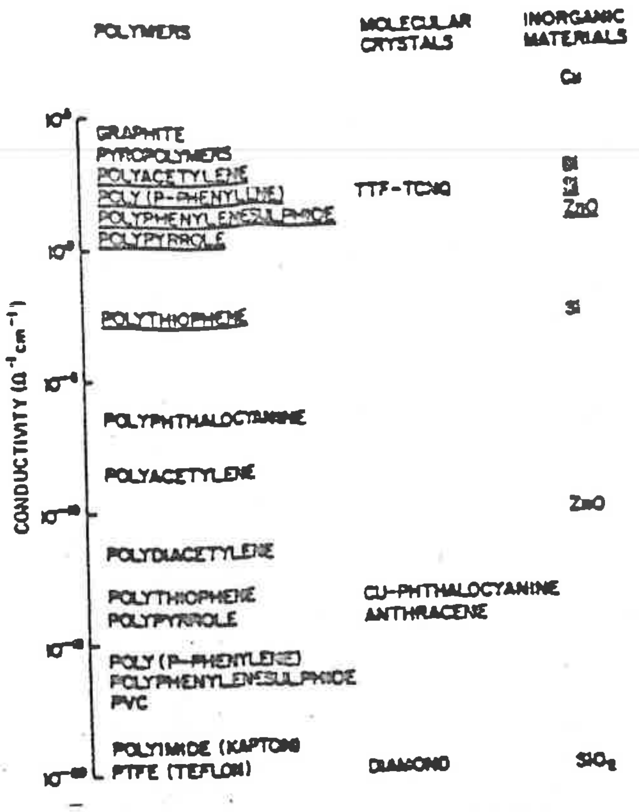

Fig 1. Conductivities of Materials

Electrical conductivity in polymers arises due to the conjugated double bonds along the polymeric chain. Also there is enhanced electrical conductivity from the introduction of impurities (doping). This is because mobile charge carriers are introduced into the system.

Because of the large chain of polymers, it is believed that the transport of charge is along the conjugated chain with inter-chain hopping as a secondary step. As in inorganic and compound semiconductors sample imperfections can play a major role in limiting conductivities.

Figure 2 shows the structures of some polymers favored for research these days. It is also of interest to note that the conjugated double bonds serve not only to aid in conduction, but also locks the chain into a rigid zig-zag.

Both n-type and p-type polymers of conducting type can be obtained through doping. The most common way of doping is to expose the films to vapor of materials like iodine and AsF_5 giving rise to p-type conductors; n-type doping can also be achieved by simply immersing the films into the solutions that will provide the n-type impurity. However n-type films are very sensitive to air and moisture — hence not thoroughly investigated.

It is interesting to observe that the $(CH)_x$ chain (eg. polyacetylene) gives rise to one dimensional conductors. This feature can be extremely useful for devices. This aspect will be discussed in a future article.

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3. N. Basescu et al., High Electrical Conductivity in Doped Polyacetylene, Nature, vol. 327, pg 403, June 4, 1987.

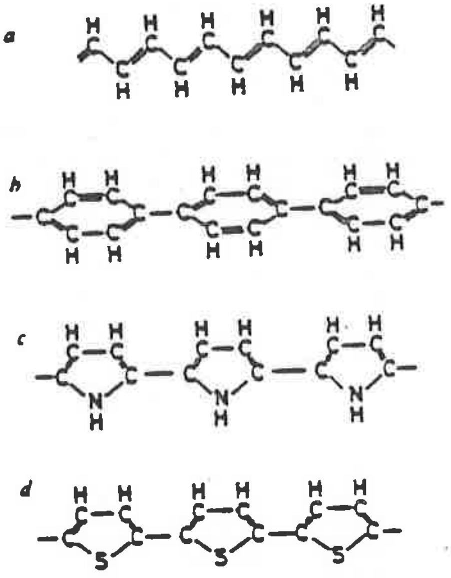

Fig. 2 Conducting Polymer Structures
a. POLYACETYLENE; b. POLYPHENYLENE
c. POLYPYRROLE; d. POLYTHIOPHENE

a. shows the zig-zag Carbon arrangement in TRANS structures;
c. & d. show the TRANS-CISOID structures.

Solar Cells

Arun Ramadorai

(Arun is one of the youngest members of SHC. He has many interests: superconductivity, solar cells, electronics, etc. He worked with a team which participated in the International Solar Car Race held in Australia last month. Seven countries participated in the race; Arun's comments on racing the car called STAR are given below).

How Do Solar Cells Work?

When sunlight hits a cell it separates the protons from the electrons and the electrons go to the back of the cell, creating a negative field. The protons go to the front creating a positive field. After that, tiny strips of metal collect the electricity and take it to a larger strip of metal where leads are soldered on. Then the lead can be connected to what you want to run on electricity.

What is a Solar Array?

A Solar array is a group of solar cells that are connected in series. A solar array can be used for many different purposes. They can be used to run lights, heat water, and run other household appliances. Unfortunately, they are too expensive to be widely used yet.

How STAR works.

Our car STAR was made with bicycle technology except for the array, drive train, and electronics. Our array is made out of Arco Solar Cells and is more efficient than multicrystal cells, which are less efficient because of all the crystals. Arco's cells are made of only one crystal. This creates less resistance, improving the flow of electricity. Our drive train is homemade, so it is easy to fix.

CELL TYPE	EFFICIENCY	COST
single crystal	88%	$8.00 each
multiple crystal	76%	$3.00 each

All but two of the twenty four cars in the race used single crystals.

The Results

On November 1, 1987 (the first day of the race) our car ran well and we passed 13 cars. That was a good day. On the fourth day our car flipped over and we were down for 11 hours. One seventh of the cells were destroyed. The next day we were back on the road. On November 11, 1987 the race was over and we beat M.I.T. at eighth place. Our team consisted of 22 members. Most of the people had worked on the car. One of the team captains is my uncle Art Boyt, instructor for the Solar Energy Department of Crowder College in Neosho, Missouri. The team that won the Trans-Australian race was the entry by General Motors.

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SQUIDS - Superconducting Quantum Interference Devices — Part II

G Radhakrishnan

Part I of this article described the basic principles behind the operation of SQUIDS. In part II, I would like to discuss the two major types of SQUIDS and their applications. In addition, I will give the status of the Superconductive Josephson technology with emphasis on the activities related to the digital systems area.

There are two different kinds of SQUID systems: one employs a SQUID containing two junctions and depends on the dc interference effects as discussed in part I which is called as a dc SQUID; the other known as a (radio frequency) RF SQUID, depends on variation of properties of a SQUID containing one junction where a RF magnetic flux is applied.

Both kinds of SQUID systems have been used for measurement of changes in quasistatic magnetic fields that are order of magnitude weaker than can be detected by the best nonsuperconductive device. The system can also be configured to measure magnetic-field gradients, voltages, currents and susceptibilities.

The dc SQUID

In the conventional mode of dc SQUID operation, its current-voltage characteristic must be non-hysteric. Basically one can ensure this condition by having an external shunt resistance of low value in the circuit, which is shown in figure 1.

When the flux through the SQUID is changed, the I-V characteristics oscillate smoothly between two extrema, which is shown in figure 2. Thus, when the SQUID is biased with a constant current, the voltage across the device is periodic in the applied flux as indicated in figure 2.

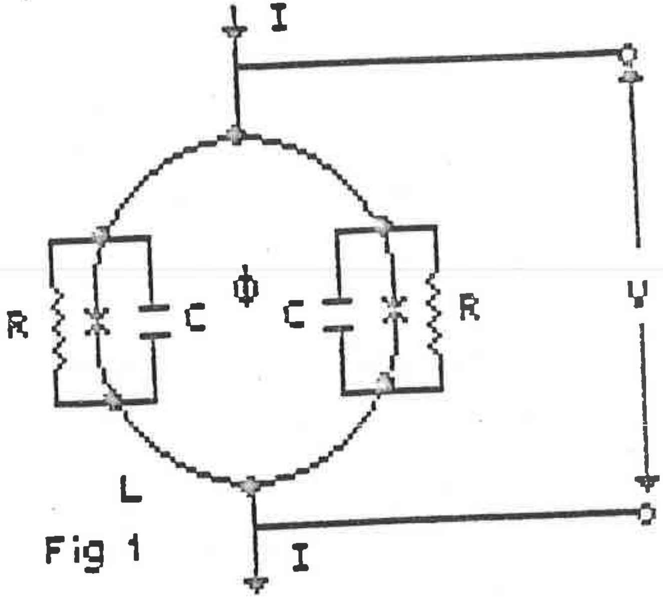

Fig 1

One normally operates the device with a flux bias of about $(2n+1)\phi_o/4$, for which the voltage is almost linear in the applied flux level.

Thus SQUID is a flux-to-voltage transducer that converts a change in magnetic flux to a change in voltage readily detectable with conventional electronics.

Figure 1 is a basic schematic of a dc SQUID biased with a constant current I and flux ϕ. Each of the two Josephson tunnel junctions shown by cross marks is shunted with its self-capacitance C and an external resistance R. The inductance of the loop is marked as L. V is the voltage across the device.

The current-voltage characteristics in figure 2(a) are those of a dc SQUID with fluxes $n\phi_o$ and $(n+1/2)\phi_o$. Figure 2(b) indicates the voltage across the SQUID as a function of flux level ϕ/ϕ_o at a fixed current bias level shown by vertical dashed line figure 2(a).

The RF SQUID

The RF SQUID consists of a superconducting loop interrupted by a single Josephson junction. The loop is coupled to the inductor of an LC-resonant circuit excited by a RF current at about 30 MHz. Figure 3 shows the basic circuit of the RF SQUID.

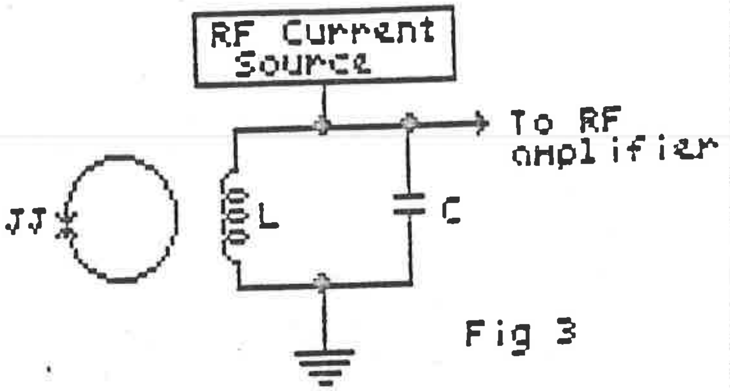

Fig 3

The amplitude of the alternating voltage across the resonant circuit is periodic in the flux threading the SQUID with a period ϕo, so that with a suitable electronics one can operate the RF SQUID in a flux-locked loop in much the same way as one does the dc SQUID. Although the sensitivity of the RF SQUID is not nearly as good as that of the dc SQUID, it is nonetheless adequate for a wide variety of applications.

Applications of SQUIDS

Scientists and Engineers in many fields have employed both RF and dc SQUIDS to a remarkably wide range of uses. Simple laboratory based measurements performed with SQUIDS include determination of the magnetic susceptibilities of very small samples over a wide range of temperatures, detection of nuclear magnetic resonance, and noise thermometry, which is the use of noise measurements to determine temperature.

Scientists used SQUIDS to study the magnetic fields generated by the heart and brain - in the area of biomagnetism. Another important application area is Geophysics - magnetotellurics, rock magnetism and paleomagnetism, for example. SQUIDS also see use in relatively large scale experiments, including gravity wave antennas and magnetic-monopole detectors.

Why Josephson Technology?

In this decade of VLSI (Very Large Scale Integration) and submicron lithography the potential for progress in the MOSFET (Metal Oxide Semiconductor Field Effect Transistors) and bipolar technologies seems to be *nearly limitless*. Further, the GaAs (Gallium Arsenide) technology, after a long struggle, appears to be poised to capture its own share of high performance systems market. In such a scenario of rapid progress and need for correspondingly large investments why would any one want to pursue something so very radically different as Josephson technology?

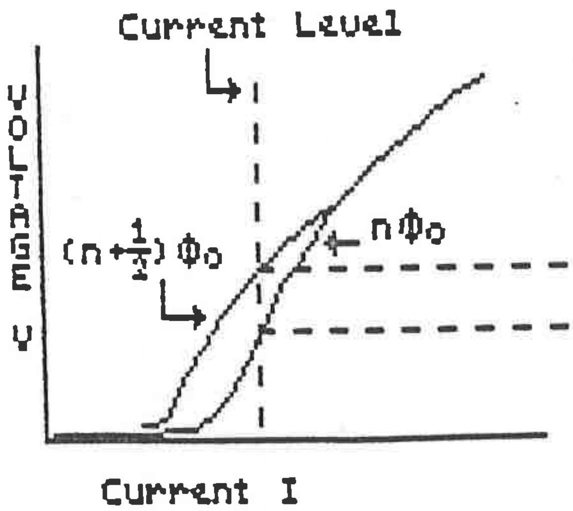

Fig 2(a)

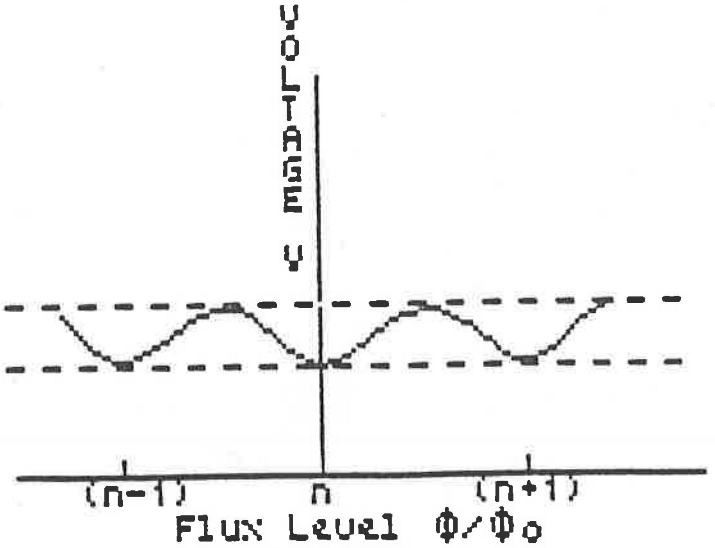

Fig 2(b)

The simple and best answer is that the Josephson technology promises even higher performance than the semiconductor technologies. For example, Josephson logic circuits using a relatively coarse minimum feature of 2.5µm (micron) switch faster than semiconductor logic circuits made using 0.5µm to 0.3µm linewidth technologies while dissipating significantly less power. Josephson technology also provided experimental sampling circuits with 3-5 PS (pico second) resolution, SQUIDS based magnetometers, voltmeters and ammeters with resolution many orders of magnitude superior to that of any other technology.

The speed of Josephson systems will further improve as one scales down the device geometries to *1um* and smaller dimensions. The high performance of the Josephson technology arises from its unique properties such as:

- * Ultra fast switching speeds
- * Very low power dissipation
- * low temperature operation
- * small signal level
- * superconducting transmission lines
- * non volatile storage of information

The above indicated features are absolutely important in the design of a large digital system.

The Josephson computer technology is at present being pursued both in the United States and abroad notably at the IBM research centers and various industries in Japan. Research efforts at the IBM laboratories are towards the development of a small, experimental signal processor with a cycle time objective of about 3-4 nanoseconds. The cycle time is determined by the performance of the various system components such as logic, memory and package.

More Next Time . . .

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Etc.

SCUIPS

o Additional work on melt processed YBC have been reported, with several variations in techniques. One of the suggestions by SHC group is to melt in an alumina crucible a mix of Y_2O_3:4BaO:6CuO at 1100-1200°C. Partial phase separation, and shrinkage of compacted powder in the crucible will be seen. This step will provide the faster fusion reaction of the components. But the compound will be deficient in oxygen i.e $YBa_2Cu_3O_{(6.5-x)}$ due to decomposition of 2CuO to Cu_2O at above 900°C. This melt reacted mix can then be ground and oxygen treated at 600 to 900°C to reestablish the excess oxygen required.

o Kilcoyne and Cywinski from U.K. report the use of bismuth oxide as a preferred sintering aid to improve the connectivity. The part substitution of Y with $Y_{0.85}Bi_{0.15}$ does not change the T_c, and also facilitates reducing the room temperature resistivity by a factor of ten.

o Hideo Ihara, et al have reported on the possibility of superconductivity at 65°C in Sr-Ba-Y-Cu-O system.
(Japanese J. Appl. Phy., Aug 1987)

o Chemistry enthusiasts would appreciate the analytical note on confirming O_2 content of superconducting perovskites using iodimetry to define the proportion of tri- valent copper. This note was published by E.H. Appelman, et al in Inorganic Chemistry (vol.26, No.20).

Merry Christmas & Happy 1988.
to Let's Levitate enthusiasts.

Mention about the SHC by David Helwig (Toronto Globe & Mail) and Ellen O. Feinberg (High T_c Update) are appreciated.

Several school students . . . from Ottawa, Toronto, Houston, Elko, etc., are planning to demonstrate Levitation in their School Science Fair . . . . Articles from them are invited.

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